

What is Ionizing Radiation?

General Description

Ionizing radiation is radiation that has sufficient energy to remove electrons from atoms. In this document, it will be referred to simply as radiation. One source of radiation is the nuclei of unstable atoms. For these radioactive atoms (also referred to as radionuclides or radioisotopes) to become more stable, the nuclei eject or emit subatomic particles and high-energy photons (gamma rays). This process is called radioactive decay. Unstable isotopes of radium, radon, uranium, and thorium, for example, exist naturally. Others are continually being made naturally or by human activities such as the splitting of atoms in a nuclear reactor. Either way, they release ionizing radiation. The major types of radiation emitted as a result of spontaneous decay are alpha and beta particles, and gamma rays. X rays, another major type of radiation, arise from processes outside of the nucleus.

Alpha Particles

Alpha particles are energetic, positively charged particles (helium nuclei) that rapidly lose energy when passing through matter. They are commonly emitted in the radioactive decay of the heaviest radioactive elements such as uranium and radium as well as by some manmade elements. Alpha particles lose energy rapidly in matter and do not penetrate very far; however, they can cause damage over their short path through tissue. These particles are usually completely absorbed by the outer dead layer of the human skin and, so, alpha emitting radioisotopes are not a hazard outside the body. However, they can be very harmful if they are ingested or inhaled. Alpha particles can be stopped completely by a sheet of paper.

Beta Particles

Beta particles are fast moving, positively or negatively charged electrons emitted from the nucleus during radioactive decay. Humans are exposed to beta particles from manmade and natural sources such as tritium, carbon-14, and strontium-90. Beta particles are more penetrating than alpha particles, but are less damaging over equally traveled distances. Some beta particles are capable of penetrating the skin and causing radiation damage; however, as with alpha emitters, beta emitters are generally more hazardous when they are inhaled or ingested. Beta particles travel appreciable distances in air, but can be reduced or stopped by a layer of clothing or by a few millimeters of a substance such as aluminum.

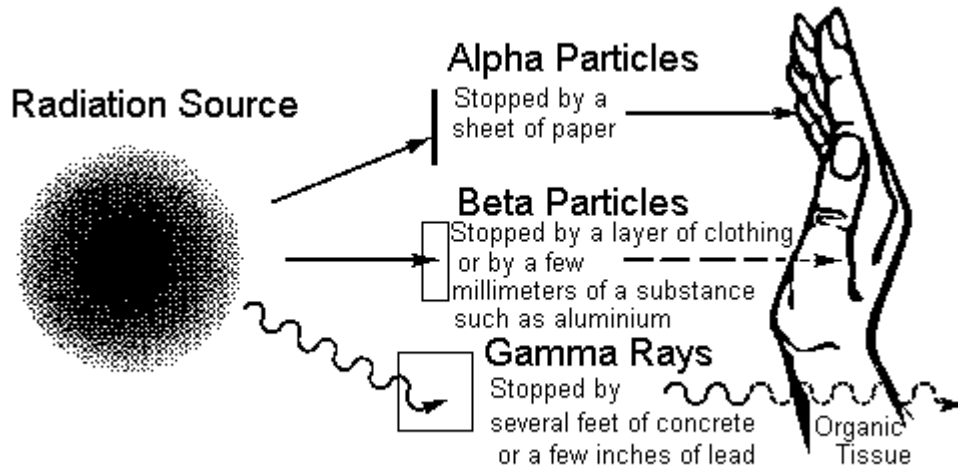
Gamma Rays

Like visible light and x rays, gamma rays are weightless packets of energy called photons. Gamma rays often accompany the emission of alpha or beta particles from a nucleus. They have neither a charge nor a mass and are very penetrating. One source of gamma rays in the environment is naturally occurring potassium-40. Manmade sources include plutonium-239 and cesium-137. Gamma rays can easily pass completely through the human body or be absorbed by tissue, thus constituting a radiation hazard for the entire body. Several feet of concrete or a few inches of lead may be required to stop the more energetic gamma rays.

X Rays

X rays are high-energy photons produced by the interaction of charged particles with matter. X rays and gamma rays have essentially the same properties, but differ in origin; i.e., x rays are emitted from processes outside the nucleus, while gamma rays originate inside the nucleus. They are generally lower in energy and therefore less penetrating than gamma rays. Literally thousands of x-ray machines are used daily in medicine and industry for examinations, inspections, and process controls. X rays are also used for cancer therapy to destroy malignant cells. Because of their many uses, x rays are the single largest source of; manmade radiation exposure. A few millimeters of lead can stop medical x rays.

The Penetrating Powers of Alpha and Beta Particles and Gamma Rays



SOURCES OF RADIATION

Natural Radiation

Humans are primarily exposed to natural radiation from the sun, cosmic rays, and naturally occurring radioactive elements found in the earth's crust. Radon, which emanates from the ground, is another important source of natural radiation. Cosmic rays from space include energetic protons, electrons, gamma rays, and x rays. The primary radioactive elements found in the earth's crust are uranium, thorium, and potassium, and their radioactive derivatives. These elements emit alpha and beta particles, or gamma rays.

Manmade Radiation

Radiation is used on an ever increasing scale in medicine, dentistry, and industry. Main users of manmade radiation include: medical facilities such as hospitals and pharmaceutical facilities; research and teaching institutions; nuclear reactors and their supporting facilities such as uranium mills and fuel preparation plants; and Federal facilities involved in nuclear weapons production as part of their normal operation.

Many of these facilities generate some radioactive waste; and some release a controlled amount of radiation into the environment. Radioactive materials are also used in common consumer products such as digital and luminous-dial wristwatches, ceramic glazes, artificial teeth, and smoke detectors.

Health Effects of Radiation Exposure

Depending on the level of exposure, radiation can pose a health risk. It can adversely affect individuals directly exposed as well as their descendants. Radiation can affect cells of the body, increasing the risk of cancer or harmful genetic mutations that can be passed on to future generations; or, if the dosage is large enough to cause massive tissue damage, it may lead to death within a few weeks of exposure.

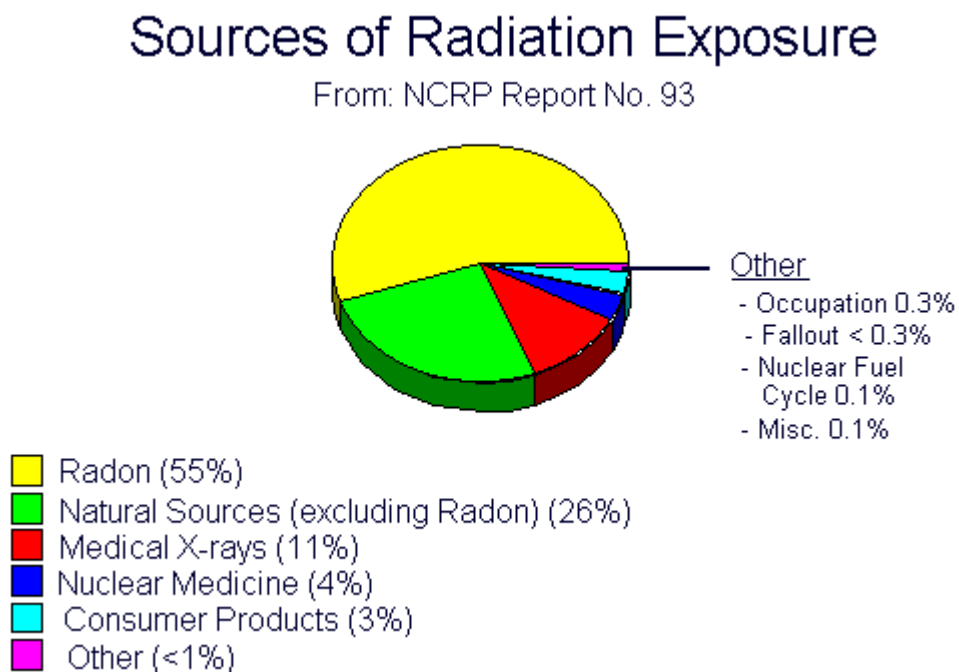
Radiation Facts

Ionizing radiation can cause changes in the chemical balance of cells. Some of those changes can result in cancer. In addition, by damaging the genetic material (DNA) contained in all cells of the body, ionizing radiation can cause harmful genetic mutations that can be passed on to future generations. Exposure to large amounts of radiation, a rare occurrence, can cause sickness in a few hours or days and death within 60 days of exposure. In extreme cases, it can cause death within a few hours of exposure.

Sources of Exposure

The ionizing radiations of primary concern are alpha and beta particles, gamma rays, and x rays. Alpha and beta particles and gamma rays can come from natural sources or can be technologically produced. Most of the x-ray exposure people receive is technologically produced. Natural radiation comes from cosmic rays, naturally occurring radioactive elements found in the earth's crust (uranium, thorium, etc.), and radioactive decay products such as radon and its subsequent decay products. The latter group represents the majority of the radiation exposure of the general public.

In addition to these natural sources, radiation can come from such wide-ranging sources as hospitals, research institutions, nuclear reactors and their support facilities, certain manufacturing processes, and Federal facilities involved in nuclear weapons production. The following figure shows the percentage contribution that various radiation sources make toward the yearly average effective dose received by the U.S. population (NCRP Report No. 93).



Any release of radioactive material is a potential source of radiation exposure to the population. In addition to exposure from external sources, radiation exposure can occur internally by ingesting, inhaling, injecting, or absorbing radioactive materials. Both external and internal sources may irradiate the whole body or a portion of the body. The amount of radiation exposure is usually expressed in a unit called millirem (mrem). In the United States, the average person is exposed to an effective dose equivalent of approximately 360 mrem (whole-body exposure) per year from all sources (NCRP Report No. 93).

Results of Exposure

Ionizing radiation affects people by depositing energy in body tissue, which can cause cell damage or cell death. In some cases there may be no effect. In other cases, the cell may survive but become abnormal, either temporarily or permanently, or an abnormal cell may become malignant. Large doses of radiation can cause extensive cellular damage and result in death. With smaller doses, the person or particular irradiated organ(s) may survive, but the cells are damaged, increasing the chance of cancer. The extent of the damage depends upon the total amount of energy absorbed, the time period and dose rate of exposure, and the particular organ(s) exposed.

Evidence of injury from low or moderate doses of radiation may not show up for months or even years. For leukemia, the minimum time period between the radiation exposure and the appearance of disease (latency period) is 2 years. For solid tumors, the latency period is more than 5 years. The types of effects and their probability of occurrence can depend on whether the exposure occurs over a large part of a person's lifespan (chronic) or during a very short portion of the lifespan (acute). It should be noted that all of the health effects of exposure to radiation can also occur in unexposed people due to other causes. Also, there is no detectable difference in appearance between radiation induced cancers and genetic effects and those due to other causes.

Chronic Exposure

Chronic exposure is continuous or intermittent exposure to low levels of radiation over a long period of time. Chronic exposure is considered to produce only effects that can be observed some time following initial exposure. These include genetic effects and other effects such as cancer, precancerous lesions, benign tumors, cataracts, skin changes, and congenital defects.

Acute Exposure

Acute exposure is exposure to a large, single dose of radiation, or a series of doses, for a short period of time. Large acute doses can result from accidental or emergency exposures or from special medical procedures (radiation therapy). In most cases, a large acute exposure to radiation can cause both immediate and delayed effects. For humans and other mammals, acute exposure, if large enough, can cause rapid development of radiation sickness, evidenced by gastrointestinal disorders, bacterial infections, hemorrhaging, anemia, loss of body fluids, and electrolyte imbalance. Delayed biological effects can include cataracts, temporary sterility, cancer, and genetic effects. Extremely high levels of acute radiation exposure can result in death within a few hours, days or weeks.

Risks of Health Effects

All people are chronically exposed to background levels of radiation present in the environment. Many people also receive additional chronic exposures and/or relatively small acute exposures. For populations receiving such exposures, the primary concern is that radiation could increase the risk of cancers or harmful genetic effects.

The probability of a radiation-caused cancer or genetic effect is related to the total amount of radiation accumulated by an individual. Based on current scientific evidence, any exposure to radiation can be harmful (or can increase the risk of cancer); however, at very low exposures, the estimated increases in risk are very small. For this reason, cancer rates in populations receiving very low doses of radiation may not show increases over the rates for unexposed populations.

For information on effects at high levels of exposure, scientists largely depend on epidemiological data on survivors of the Japanese atomic bomb explosions and on people receiving large doses of radiation medically. These data demonstrate a higher incidence of cancer among exposed individuals and a greater probability of cancer as the level of exposure increases. In the absence of more direct information, that data is also used to estimate what the effects could be at lower exposures. Where questions arise, scientists try to extrapolate based on information obtained from laboratory experiments, but these extrapolations are acknowledged to be only estimates. For radon, scientists largely depend on data collected on underground miners. Professionals in the radiation protection field prudently assume that the chance of a fatal cancer from radiation exposure increases in proportion to the magnitude of the exposure and that the risk is as high for chronic exposure as it is for acute exposure. In other words, it is assumed that no radiation exposure is completely risk free.